Operational Multi-Sensor Oil Spill Surveillance Program

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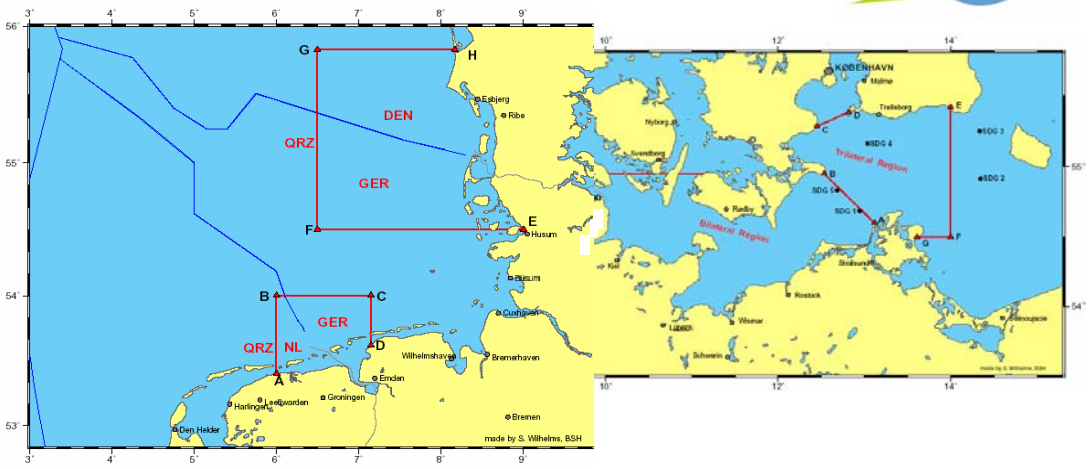
Content

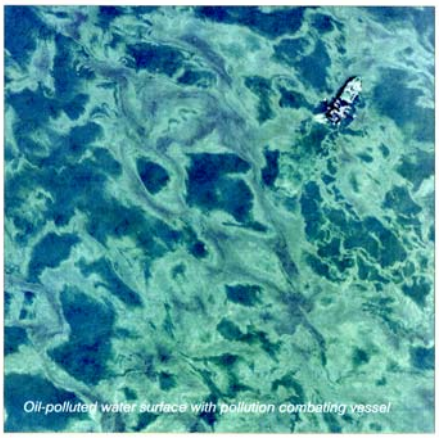
- Introduction – situation and task
- Combined system
  – aircraft and satellite
- Sensor system of German Do228
  – optimized for oil spill surveillance over water
- Use for oil & ice?
- Summary

Surveillance area North- & Baltic Sea



- 115.000 km² area of responsibility
- Bad weather conditions
- Wadden sea with strong tidal currents & wide tidal range
- Narrow shipping lanes
- Very high traffic density
- Highly populated coastal areas
- Sensitive ecosystem

TASK: Surveillance for maritime oil pollution



- Co-ordination and optimisation of ship operation during oil spill combat
- 24 h, weather independent surveillance (international agreements Bonn, Helsinki, MARPOL)
- Detection of unintentional & deliberate pollution
- Amount, kind, spatial distribution of pollution
- Verification; collection of evidence

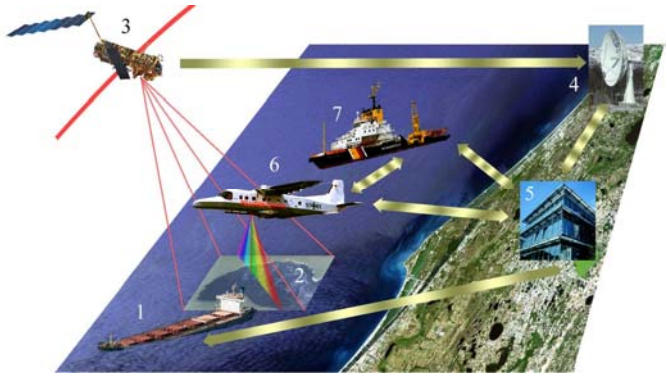
There are secondary tasks, but aircraft sensor system is optimised for above purposes (over water)

Partners & Operation

- Two "DO228" aircraft are equipped with a multi-sensor system (different systems)

Federal Ministry of Transport, Building and Urban Development
- responsibility

Central Command for Maritime Emergencies (CCME)
- *Pollution combat*
- *Coordinate operational surveillance*



BfG
- Scientific advisor
- Purchaser / Coordination equipment with sensor system

German Naval Air Wing 3 „Graf Zeppelin“ (MFG 3)
- Fly / operate / maintain

Industry
- build sensor system (current phase: OPTIMARE)

Combined system – synergetic effects

Aircraft:

- Flexible, high resolution routine (+ accident) surveillance
- Pollution combating assistance
- Multi-sensor system: much more information (-> later)
- “Ground” truth; preservation of evidence

Satellite (oil spill pollution services)**:**

- EMSA & MarCoast (European GMES-project; BfG: user and validation activities)
- SAR only: Indicates possible pollution
- Limited repetition rate, fixed (known) times
- Partly-automatic NRT analysis, first alert; good overview (large area); cheaper image price

Drift model: Stronger integration planned

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- Synergetic effects
  – aircraft and satellite
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    surveillance over water
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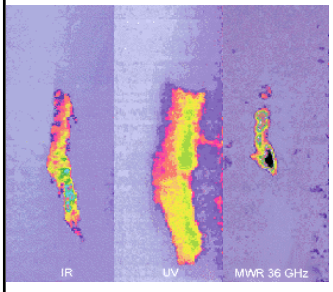
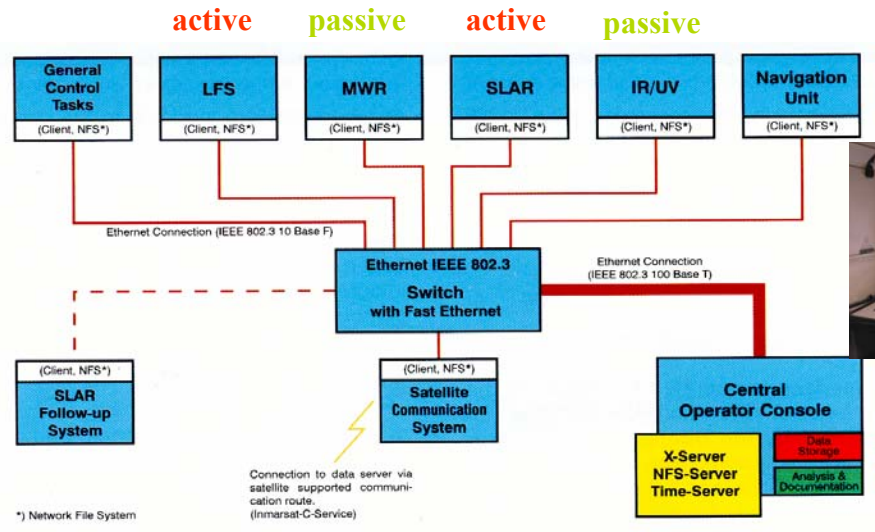
Overview of the sensors on board of German Do228



IR **UV** **MWR**

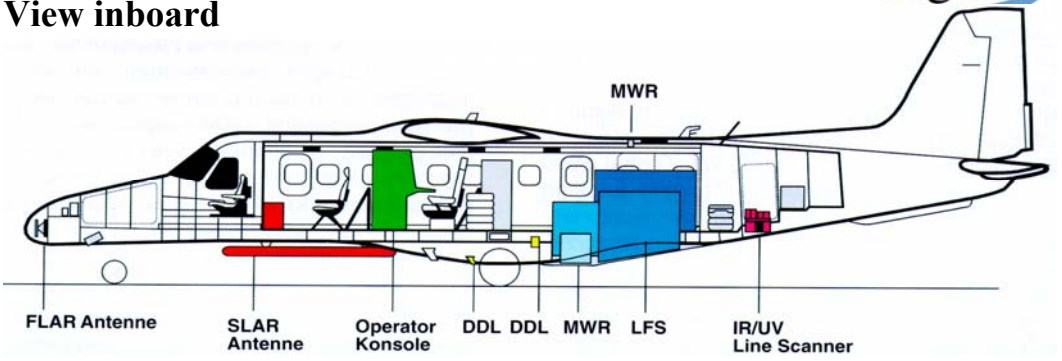
- Wide-range: (±30 km)
  - Detection of position of possible pollution
    - Sideward Looking Airborne Radar (SLAR)
- Narrow-range: (±250 m)
  - Oil indicators & Area
    - SLAR / IR/UV /Laser-Fluoro-Sensor (LFS) → Volume
  - Layer thickness (thick / thin layers)
    - Microwave-Radiometer (MWR) / LFS
  - Classification of oil (and chemicals)
    - LFS
  - Securing of evidence
    - Forward Looking Infrared Camera (FLIR); active
    - Video system, cameras
  - Additional support for pollution combating
    - Communication

General structure of the MEDUSA-sensor network



One central operator console

View inboard

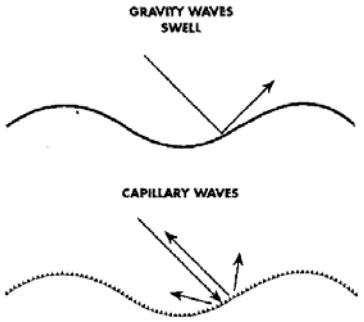


- Balance between endurance / weight & number sensors

FLIR

Principle of oil detection by SLAR (Sideward looking airborne radar)

- X-band-waves (ca. 10 GHz) are back-scattered by ships and capillary waves
- Thin oil layers smoothen sea surface roughness
- => reduced backscattering
- => „black“ spots on radar image



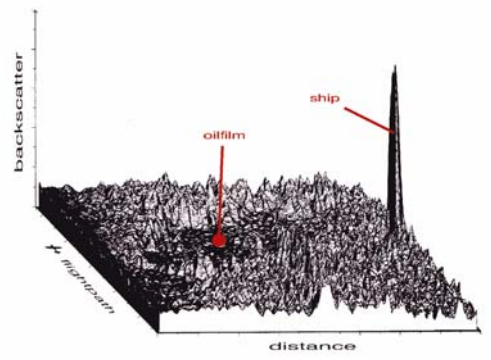
= indirect effect

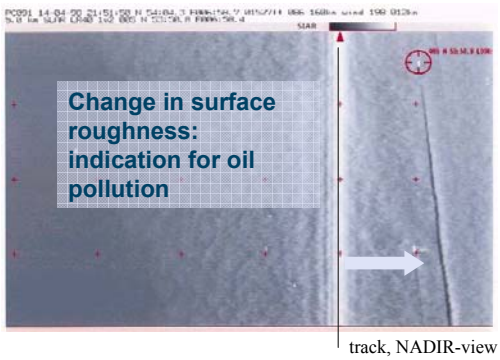
Possible other sources for „dark spots“:
e.g. windless areas, algae, upwelling water, sandbank, fish oil

=> Signal can be misinterpreted (SAR satellite similar)

=> Aircraft near-range sensors required

SLAR backscatter signal

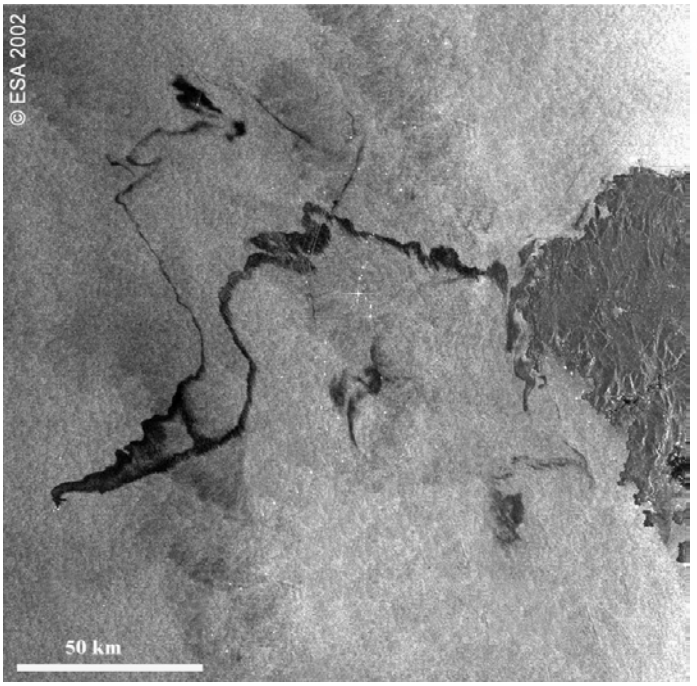




Envisat ASAR image (satellite)

shows tanker, Prestige, 100 km off Spanish coast

20.11.2002



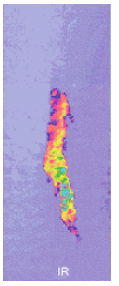
Credits: ESA

IR/UV – 2 channel line-scanner (passive)

bfg Bundesanstalt für Gewässerkunde

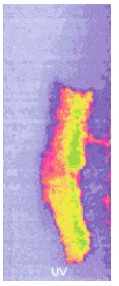
IR-Channel

- Thermal emission of the sea surface (8.5 - 12.5 µm)
- Lower emissivity of oil (than water)
  => oil layer seems colder than water surface
- However: oil films of thickness > 0.5 mm absorb sunlight,
  => temperature increases & oil layer appears warmer
- THERMAL REFERENCE:
  Two controllable field-filling blackbody reference sources
  => absolute (temperature measurement)
- Independent from daylight -> also operating at night



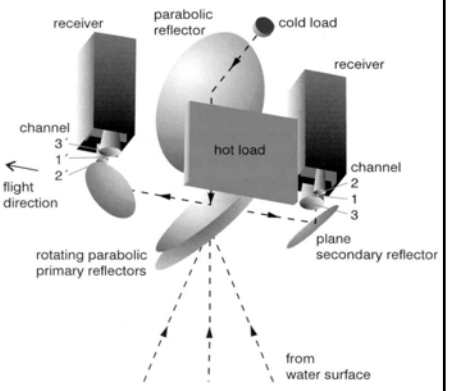
UV-Channel

- Measures sun-light reflected from sea surface (320 - 380 nm)
- Very thin oil films (>0.01µm) can be determined due to short wavelength of the UV
- Limited to daylight conditions and to sufficient visibility



Microwave-Radiometer (MWR)

- Line-scanner (Swath 476m@100ft; 72°)
- Wavelengths (reserved): 18.7, 36.5, 89 GHz
- Atmospheric measurements @ 89 GHz
- Oil layer thickness determination between 50µm to the mm range

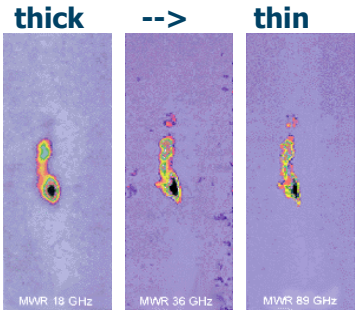


Advantage:

- Insensitive to water vapour
- Day and night operability by analysing the thermal microwave radiation

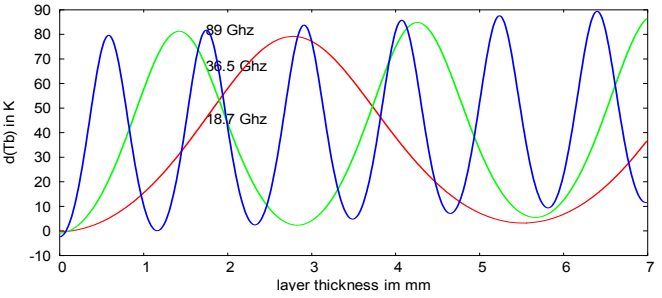
However:

- High extinction of microwave in water restricts measurements on surface layers.

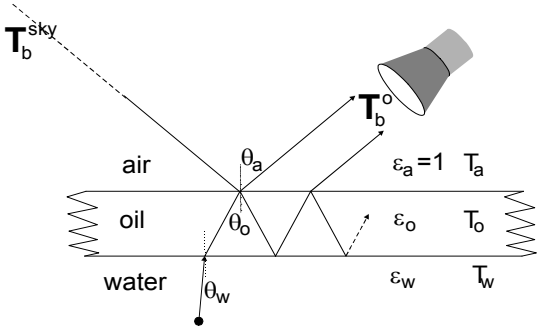


Principle of MWR

- Interferences between boundary layers oil/air and oil/water => oil layer thickness determination (50µm to 3mm)

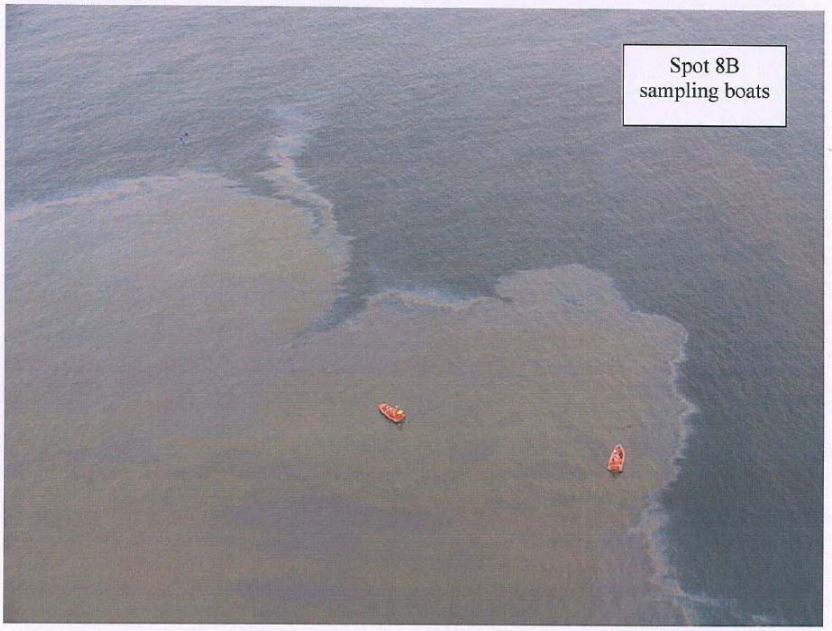


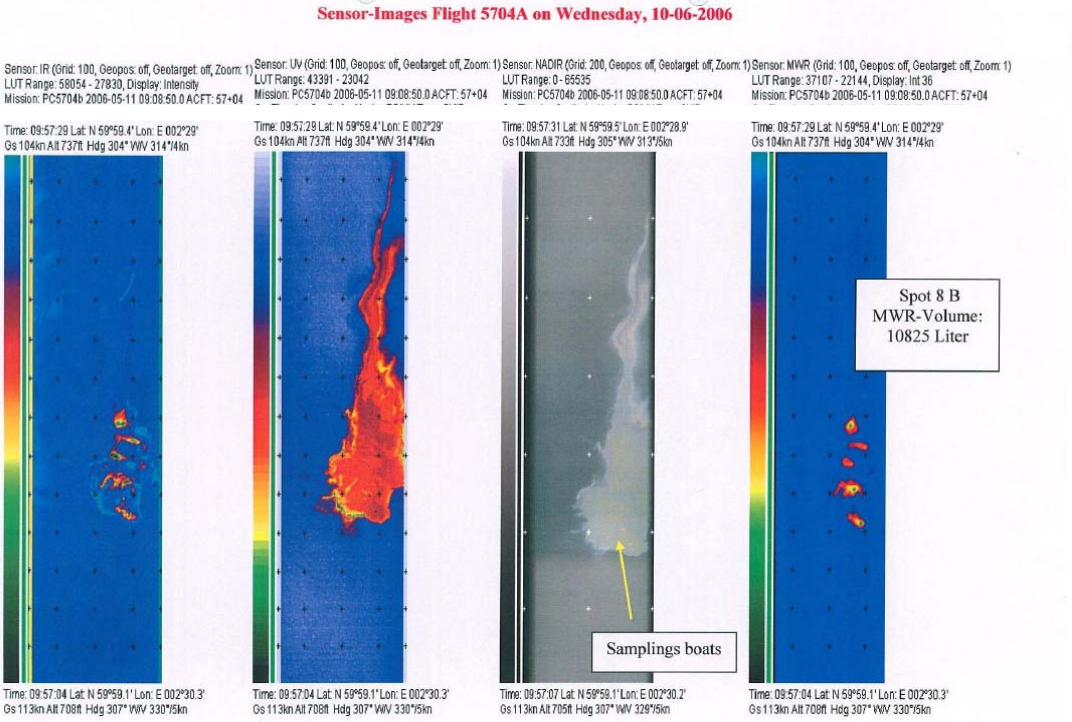
- Thermal microwave radiation



- Simultaneous measurements of multiple frequencies prevent ambiguousness
- Simultaneous detection of atmospheric radiation for calibration (particularly for rain and rain clouds)

NOFO

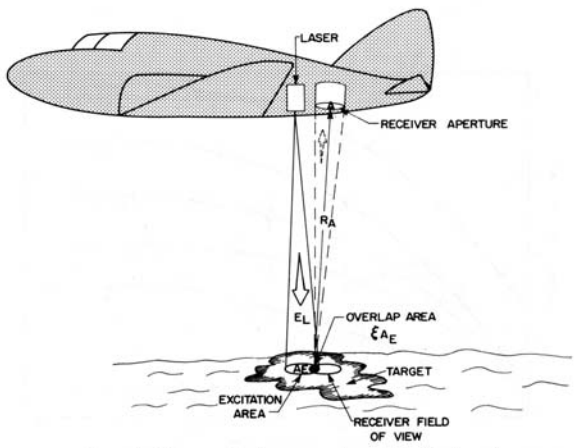




Thanks to MFG3

Laser-Fluoro Sensor (LFS)

- Determination of oil layer thickness within 0.1 to 20 µm,
- Identification and classification of the oil types



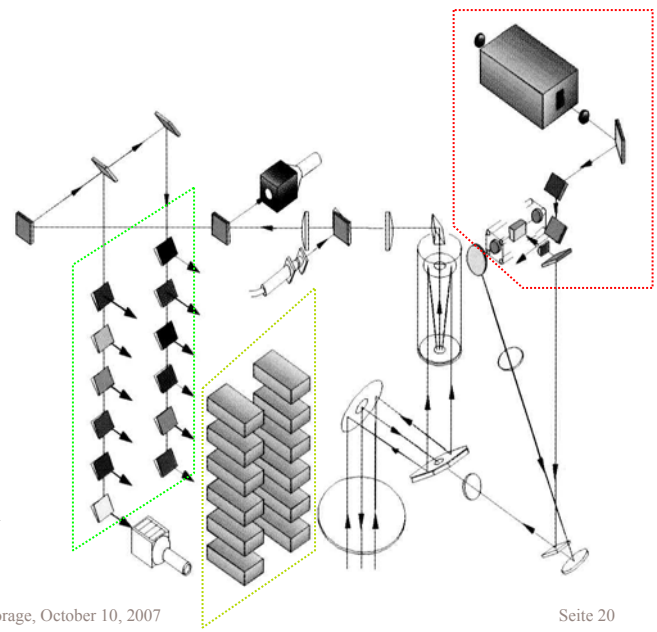
Schematic of the geometrical arrangement associated with a laser fluorosensor.

- **to prevent false alarms: discrimination of natural oil alike substances on the sea surface and of mineral oil,**
- **Detection of oil quantities below the water surface**

- Currently alignment proplems
- On-sea campaign for sensor testing (e.g. LFS) planned for next year

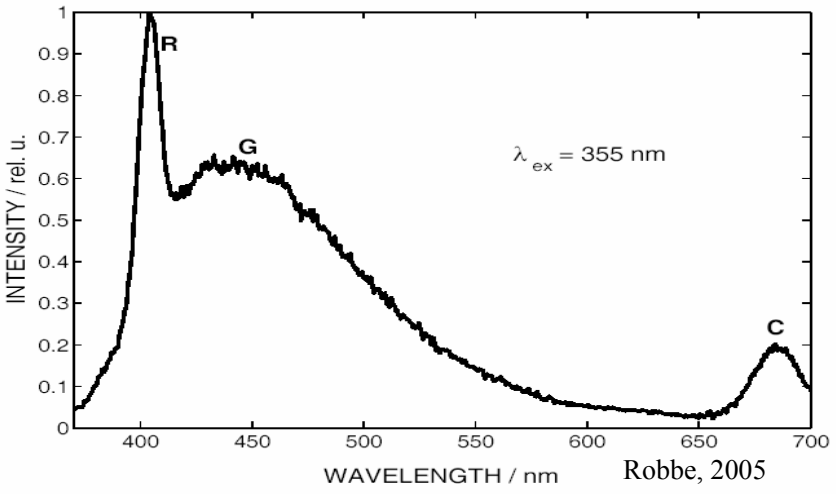
Setup of the LFS

- Flight height 1000 ft typical (eye safe > 300ft)
- ~ 10m pixel to pixel; conical scan pattern
- IFOV ~ 1.5 m * 1,5 m
- Pulsed high-energy-laser XeCl excimer 308 nm; 150 mJ
- Photo multiplier
- Dichroitic beam-splitter
- Optical bandwidth ~10 nm
- Interference filter



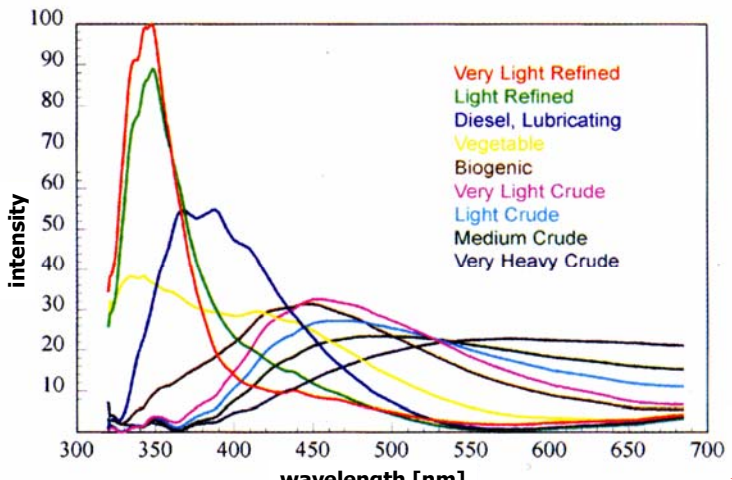
Principle of LFS

- Layer thickness: ratio between back-scattered Raman-signal from and outside the oil film,



Robbe, 2005

Fluorescence measurements of oil species; excitation @ 308nm



- Classification by a principal component analysis of the fluorescence signals
- determination of eigenvalue-spectra / correlation with oil class catalogue

Detection wavelengths (12 channels)

Fluorescense
Raman Scattering

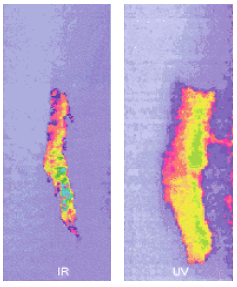
Fusion & comparison of sensors

	Visual	SLAR	UV	IR	MWR	LFS	Satellite (RADARSAT)
Range @ 300m flight altitude	approx. ±3km	wide, ±30km	narrow, ±250m			narrow, ±75m	300x300km
Classification capabilities	no	no				yes	no
sensitivity on oil film thickness	N.A.	N.A.	>0.01 µm	>10 µm	50 µm to 2.5mm	0.1 µm to 20 µm	N.A.
Spatial resolution	high	60m by 30m (perp.)	3.5m	3.5m	>5m	10m pixel-to-pixel distance	50m
Detection of oil spills below surface	no	no				yes	no
Operating at night	no	yes	no	yes	yes	yes	yes
Film thickness determination	Appearance of oil slick	no			yes, 50 µm to 2.5mm	yes, 0.1 µm to 20 mm	no
Measuring geometry	visual	Line-by-line, 20 Hz				Conical, 5Hz	image
Impaired by	no	no	clouds	clouds	no	clouds, flight altitude	no

- Depending on the sensor there are further limitations e.g. due to size of the spill, weathering state, weather conditions (too much or too little wind)

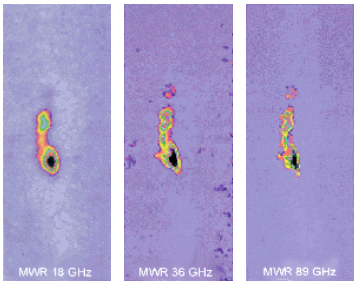
Fusion of the sensor data

Determination of the oil layer extension



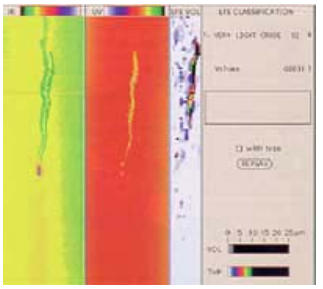
IR UV

Determination of the oil layer thickness thick --> thin



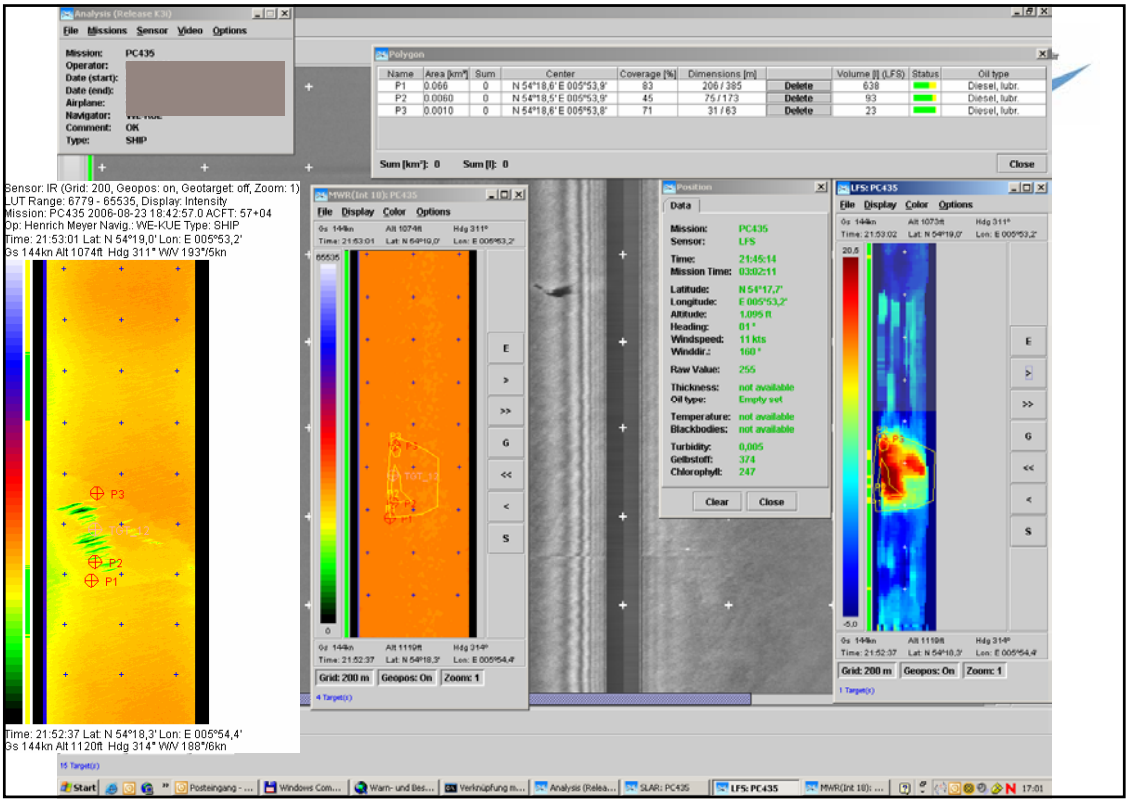
18 Ghz 35 Ghz 85 Ghz

classification, thickness of layer



IR UV LFS

- Information obtained = combination of all sensors & near real-time on-board analysis (optimised for oil on water)
- All data stored in database => on-ground re-analysis possible



Some ideas about OIL & ICE – Input for workshop discussion

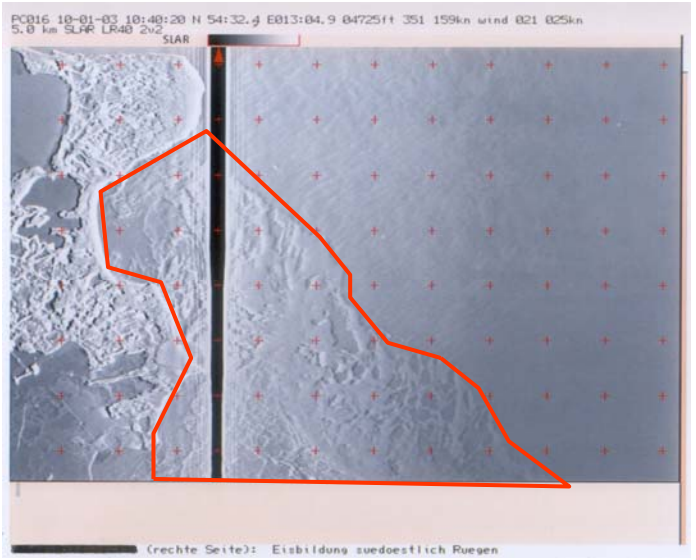
- System optimized for detecting oil on water
- Suitable for detecting oil on (in / under) ice??

- So far: no experience
- Ice/Oil shows much more possible variations than Water/Oil !
- Some points/ideas for discussion!

- Distinguish between:
  - Physical principle suitable
  - Technical realisation suitable
  - Existing analysis software suitable (database: on-ground re-analysis possible)

SLAR images of ice

- Needed for finding oil slick -> otherwise like “finding a needle in a haystack”
- Signal of ice similar to signal of land
- Oil ON ice should be possible to detect (area)
- Expected to be difficult to distinguish from water on ice or from smooth ice surface



UV

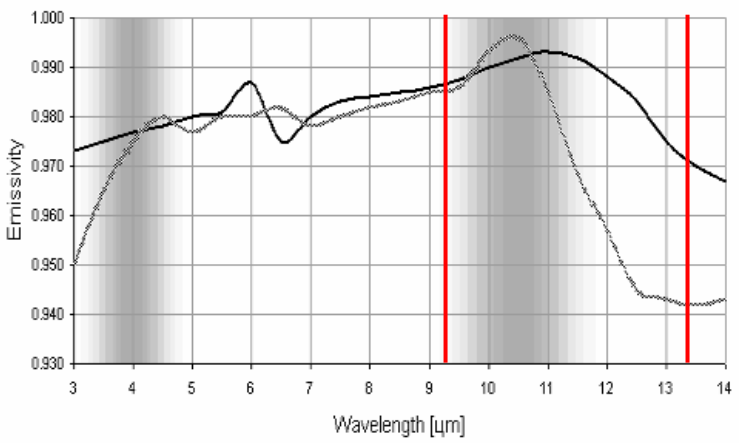
- Detection principle based on higher reflectivity of oil compared to water

=> should work similar for oil on ice

MWR

- Emissivity in microwave regime seems to depend on kind of ice
- But: sensor expected to provide some information about oil & ice

IR? - Emissivity of ice (grey) and water (black)

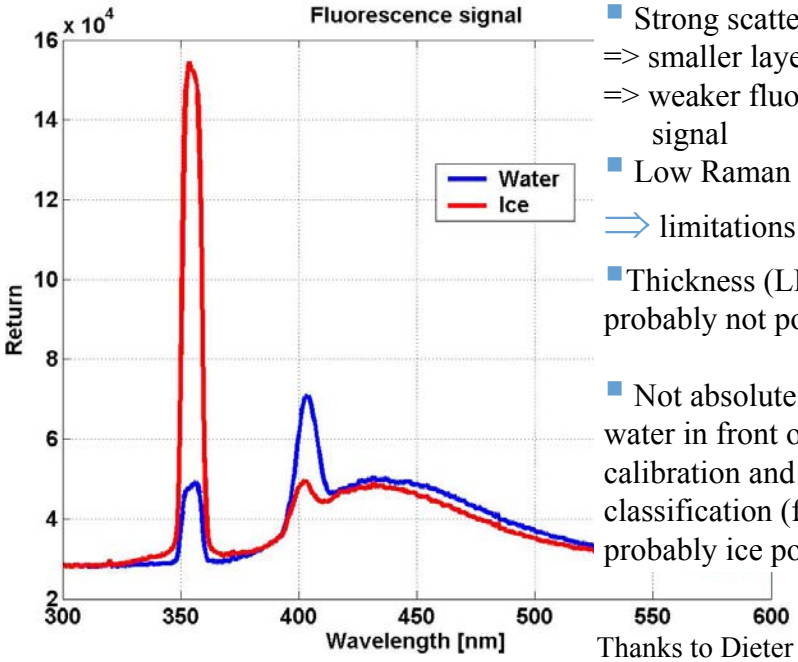


- Emissivity of ice and water in IR comparable: detection should be similar, too
- Limit by range of BB for calibration?

Figure based on data from the MODIS UCSB emissivity library (NASA/CFSC/SBRC):

Source of figure:
http://www.comp.glam.ac.uk/pages/staff/pplassma/MedImaging/PROJECTS/IR/CAMTEST/Icewater.htm

LFS – fluorescence of (tap) water and ice



- Strong scattering
=> smaller layer
=> weaker fluorescence signal
- Low Raman

⇒ limitations on ice!

- Thickness (LFS) probably not possible

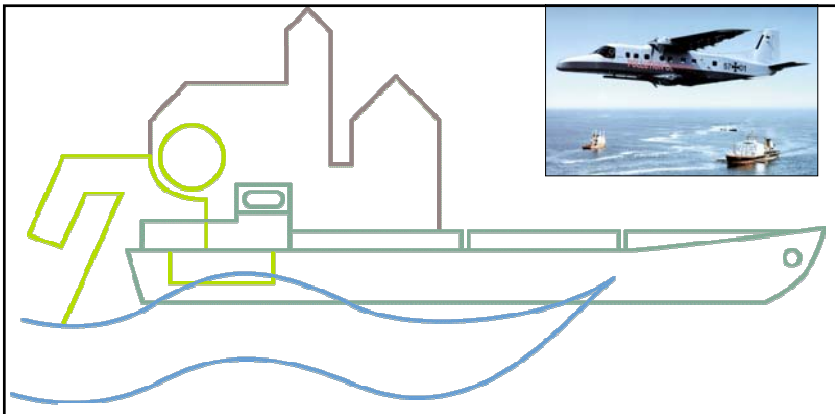
- Not absolute measurement – water in front of oil needed for calibration and as basis for oil classification (for re-analysis probably ice possible)

Thanks to Dieter Lippert

Conclusions and outlook

- Satellite input to aerial surveillance used for alert of potential spills and good overview
- German Airborne multi-sensor system in DO228
  - optimized for oil spill surveillance and detecting oil on water
  - Combination of sensors provide – on-board in NRT – a multitude of information
    - e.g. confirmation as oil, area, volume, type
  - Part of information even at night and through clouds
- Oil on ice?
  - so far no experience
  - Sensors & software optimized for use on oil on water
  - There are some limitations (more complex, more difficult detection) but also some potential
  - More would have to be shown by
    -> further theoretical considerations
    -> experiments

-> INPUT? DISCUSSION !



Thank you for your attention!

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